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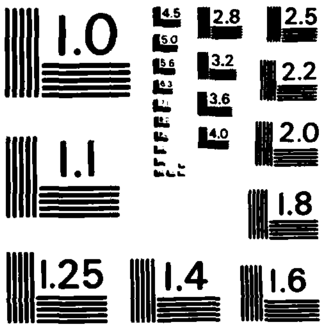

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Risk Assessment Preprocessor
(RAPP)

by

Colin Hammon
Joseph Augusta
Susan Fitzgerald

Administrative Sciences Corporation
5590 Backlick Road
Springfield, Virginia 22151
(703) 642-1250

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Colin Hammon
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Introduction

Department of Defense directives and policies require risk to be explicitly considered in the management of acquisition programs. In compliance with these directives, program managers conduct risk assessment in some form or another. However, almost universally, project managers do not use the variety of quantitative techniques which are available to do risk assessment. Risk assessment is generally thought of as an additional requirement placed on the program manager rather than a management tool. In effect, the assessment of risk and a statement of its expected effect on program schedule, cost and performance is perceived as an additional hurdle for the program manager (PM) to surmount. The basic problem is that there is no way for the PM, who is new to risk assessment, to knowledgeably select a technique or to easily implement it once selected.

For this reason, the Navy's Office for Acquisition Research tasked Administrative Sciences Corporation to develop "a management oriented procedure to simplify the selection of the most appropriate risk assessment technique(s) so that project managers will use them to improve management of their programs." Under this tasking, we examined the different techniques available for risk assessment and concluded that network simulation[1] is both cost effective and feasible for use in almost all acquisition programs. Network simulation has more general utility and applicability than is commonly believed; it is the most flexible technique available that is also analytically rigorous. Networks (we use the term here to refer to both network and decision analyses) do not have to be extremely detailed to be useful. They can be as simple or complicated as desired. Because the cost of preparing a network is a function of the number of activities in the network, a fairly simple network can be useful to, and within the reach of, the smallest acquisition programs. However, in the past risk assessment has been hard to understand, the necessary tools have not always being available, and it has been difficult and expensive to get started.

Two things must be done: 1) develop a network and 2) use the network to do risk assessment.

Traditionally, creating the network has been a time consuming, expensive and tedious task that appears to take more effort than it is worth. It certainly has not been a job for the neophyte. The second step requires a network simulator software package, the network simulator. (It is this second step that distinguishes risk assessment from PERT and CP/M.) There are several network analysis software packages around, most of which are proprietary and none of which are easy to use. They are almost incomprehensible to the non-specialist. These difficulties have led to PMs either passing on doing quantitative risk assessment or to use experienced, and expensive, help - always in the private sector. "Getting started" is usually the point where the expensive senior analyst enters the picture; the senior analyst provides the "getting started" capability.

As a result of ~~our~~ a critical review of the existing procedures and available software packages, it was ~~we~~ concluded that "front-end" help in getting started was necessary - specifically, assistance in network creation and data preparation and input. We created the Risk Assessment Preprocessor (RAPP), as created to provide this help. RAPP is a computer-based procedure for simplifying the process of creating networks and preparing the data for use with a network simulator. RAPP is interactive, easy to use software which will help the user create a network of program activities and input distribution parameters. It does not actually do the risk assessment. RAPP's output is a data file which is input to one of the several currently available network simulators. It is a tool that makes risk assessment using Monte Carlo simulation easier and less expensive because it reduces the need for senior analysts to structure the network and prepare the data file for input to a risk assessment package. RAPP allows risk assessment to be used more easily as a tool for project management. It is a practical tool for project managers who want to use risk assessment.

What is Risk Assessment?

Risk Assessment is the formal method of providing the program manager with quantitative estimates of the probability that major schedule and cost goals, particularly IOC, will be

reached and putting bounds on these probabilities. It includes specifying the necessary activities in the acquisition program, collecting cost, schedule and performance data, and generating alternatives in order to apply risk reduction and control. The outputs of Risk Assessment are quantitative statements about the level and distribution of program risks.

Risk assessment provides the quantitative analysis necessary for deriving probabilities for attaining program objectives based on a systematic examination of a project's activities and deadlines. With risk assessment, one can speak of having a 75% probability of achieving scheduled IOC. These probabilities are not based on subjective, qualitative "feelings" of the PM, but instead are derived from a structured, quantitative analysis of the program. Thus, they are **not** the translation of the high, medium and low risk assessments into probabilities, but a systematic examination of cost or schedule objectives based on a consideration of activities required to meet IOC, the dependence of activities on each other, the time or cost required to complete each activity, and information about how likely (i.e., the probability) a particular cost or schedule estimate is. Risk assessment is not limited to a one time prediction of the critical path, as is PERT or the Critical Path Method. A well structured risk assessment remains valuable throughout the program's life to help the PM evaluate his goals. As intermediate milestones are met, or not met, risk assessment can be used to re-evaluate intervening cost and schedule effects and assess the impact of these intermediate milestones on IOC. It can also be used to evaluate the impact of program modifications. A program modification might impact cost and/or schedule of several inter-related activities in different directions. The value of a structured risk assessment is in helping the manager to evaluate the total effect on cost and scheduled IOC. Implicit in such an assessment is the ability to identify and react to problem areas in a timely way (before the down stream effects are set in concrete).

In response to this requirement for risk assessment, the PM normally makes a subjective estimate of whether the project is a high, medium, or low risk project. This estimate is usually derived by considering such factors as whether the program is technologically advanced, whether

off-the-shelf major components (such as engines or avionics) are being used, and whether there are managerially complex issues involved. Thus, the judgment made on the program's "riskiness" is based on serious consideration of major issues. This judgment is not translated into quantitative statements about meeting milestones, or cost or performance goals. The weakness in this type of risk assessment is not immediately apparent. Early briefings on a program's schedule (or cost) appear sound (as do progress reports when nothing is going wrong), but if things begin to go poorly or if there are major changes to a program, difficulties can arise. Briefings then appear to be based on wishful thinking or a lack of awareness of the difficulties that face the project. Once schedule and cost problems become visible, both the project and the PM are in trouble.

An indirect benefit of formal risk assessment is that it provides structure, and consequently improved communications among program personnel with diverse and sometimes conflicting objectives. Quantifying the unknown aspects of program schedules, costs and performance provides a common basis for interpreting the potential program impacts of these unknowns. Structure leads to a better understanding of the costs and benefits of program decisions. Quantification, in terms of probability distributions and expected values of each outcome, provides a common measure of estimated costs and benefits. This enhances the program manager's ability to assess the relative importance of assumptions and expert opinion on which schedule, cost and performance estimates are based.

The most analytically rigorous method of risk assessment is stochastic network analysis. The most familiar network analyses for management are PERT and CP/M. However, PERT is a deterministic approach and is not a risk assessment model. Risk assessment requires probabilistic network analysis. Probabilistic network analysis (stochastic network simulation) is generally applicable to all phases, at every level of weapon system program management, and provides a choice of level of detail for analysis in program management. By accounting for the impact of program uncertainties on cost, schedule and technical performance, probabilistic

network analysis can contribute to the discovery of potential problems and opportunities and the evaluation of alternative courses of action. Stochastic network analysis, with its generality and theoretical rigor, is therefore the risk assessment technique required by management in order to implement a meaningful risk assessment program.

The most powerful network processors incorporate Monte Carlo simulation. In Monte Carlo simulation, parameters are specified for various distributions underlying the program being studied. Repeated sampling from these underlying distributions is used to generate estimates of the distribution parameters for the dependent variables of the model. Several commercial packages are available, along with computer code required for their implementation. Input/output, detail and formats, as well as completeness, vary, but all are based on the same principle. The network is simulated many times (100-1000) and the outcomes of each replication tabulated. One traversal through the network has little meaning by itself. However, many repetitions will converge to the expected value of the program outcome. The distribution of observed program costs' dispersion, mean and median provide additional information. Different assumptions can be input and the simulation run repeated to see the impact of different program alternatives.

Getting Started:

Network simulation is capable of being used routinely by program management as an integral part of an existing management information system for program planning, scheduling, resource management, costing and control. Getting started is the hard part because existing stochastic network software packages do not meet criteria such as easy to understand and perform, output easily understood and responsiveness.

There are four logically distinct parts to performing risk assessment using network simulation:

1) determining the activities and events required and their order (sequence),

2) collecting and analyzing resource information (time and cost) about each of the activities and events,

3) entering the network and resource information into a network simulation processor which will provide estimates of the expected schedule times or costs and confidence limits for these, and

4) manipulating the data using the network simulation processor to generate management-oriented statements about risk.

For purposes of developing, maintaining and updating a risk assessment management system, these tasks are logically separated. *RAPP/VERT* produces an integrated approach with the capability of separate adjustment to the component parts.

Network Development. For risk assessment to be useful for program scheduling, resource allocation, costing and control, the basic networks must be specified at a level of detail useful to management. Sufficient detail is necessary when constructing networks so that the network provides realistic projections of meaningful tasks. Too little detail makes projections of questionable usefulness. Too much detail means excessive data collection costs, input costs, computer computation costs and - eventually - output too detailed for management use in review and control.

When selecting the events to be included in the networks, one should consider factors such as specific milestones of interest (e.g., DSARC milestones), appropriate level of events of interest in the acquisition process, availability of data, and the existence of acquisition

program interfaces with other SYSCOMS, Navy laboratories, Navy corporate-level management, other government agencies and contractors. When a tentative group of activities is identified, some review is desirable to assure accuracy and clarify details.

Data Collection and Analysis. Once the activities and events are established, critically important data must be collected, including estimates of the minimum, most likely, and maximum **time** and **cost** and/or cost estimating transformations for each activity. Event data include specifying whether any event is an origin or terminating point for the network, and the node logic associated with it.

Node logic refers to the rules of stochastic network processors which determine when and how activities are initiated. An activity exiting from a given node may be started upon the completion of one or more activities or may be started according to some preset probability distribution. Activities can also be initiated based on the observed values of cost, time or *performance for some earlier activity in the network.*

Risk is introduced by specifying probability distributions for time of completion, cost or performance variables. The preset distributions are compared with random numbers generated by the program. The observed values of cost, time and performance are then generated according to the value of the observed random number.

Input Data into the Network Simulator. The network and data on activities and events must be inserted into the network simulator. RAPP does this automatically. Data sources include existing program data bases, historical data from other programs and subjective judgment of experienced personnel. As experience is gained, a database should be developed with representative data for each type of information necessary.

Do Risk Assessment. Once the data is inserted, the network processor simulates the program

many times, thereby generating useful statistics. Distributions of time, cost and performance variables can be displayed for each terminal event. Measures of **criticality** and **optimality** for various paths through the network can be calculated. **Criticality** is a number which states the probability that a given path will be critical. The **optimal** path is the opposite of the critical path. The probability distribution functions generated by the program also allow calculation of confidence limits (the range within which time, cost or performance can be expected to fall with some selected probability). The shape of the probability density functions for a given terminal node also provide intuitive insight concerning uncertainty.

Various parameters such as durations and costs can be changed and the processor re-run in order to determine the sensitivity of results to particular assumptions. Such what-if analyses can be particularly valuable in determining weak links or critical sub-elements of the program's schedule and cost projections.

Because a project may succeed or fail in many ways, each path can end in a different terminal node. A histogram showing the probability of reaching each terminal node can be examined and compared with the (C/T/P) distributions for each terminal node. This provides valuable insight regarding possible program adjustments to activities along each of the paths leading to a particular termination. Such information indicates activities where reallocation of resources could improve the chances of decreased overall time and cost or increased overall performance.

What Does RAPP Do?

RAPP is a computer-based tool designed to help Program Managers and their immediate staff create networks to be used for risk assessment. RAPP focuses on the areas that have been found to be the most time consuming and most expensive. It uses a series of prompts specifically tailored to the DoD's acquisition process to (1) help in structuring the network, (2) insure consistency of internal network logic and (3) provide automated input to the risk assessment package.

1. Help in Structuring the Network. Any acquisition project has a series of objectives (called milestones) and a series of tasks that must be performed to meet these objectives. A network uses activities and events (called arcs and nodes) to represent this situation. In building a network, a PM must first create a list of activities and then order these in proper sequence. Proper sequence includes consideration of predecessor activities, if any, and branching from completed activities, successor activities.

Using a network, or developing one, requires the PM to think about, and discuss within the PMO, the details of the program, problem areas and opportunities to be exploited, and the order of events and their dependencies (what activities must be completed before others can begin). The amount of detail in any network is a matter of choice. Any activity in the network can be expanded into a subnetwork with subactivities. If a PM wanted to examine a particular activity or set of activities more closely, he could expand the activities of interest into a more detailed subnetwork.

RAPP assists in this process by first asking for the list of milestones and the activities which must be performed to meet these milestones. The user has complete freedom to add to, delete from, or modify this list as network development proceeds. Second, RAPP helps the user by ordering the activities. RAPP does this by asking a series of questions about the milestone dates, the time and cost distributions of predecessor activities, and program termination. At any point in the process, or after a risk assessment has been performed, the user can expand any activity into a partitioned subnetwork or aggregate several activities into one activity to develop a macro network.

2. Insuring Internal Consistency. One of the major problems with constructing networks is that, with so many activities, the human mind easily loses track of their interrelationship. RAPP incorporates internal logic to insure that activities which must be completed or events

which must occur before other activities can start are so recorded, and that resources (time and cost) are applied to each activity.

3. **Output Data Files.** Even with a completed network, one cannot automatically do risk assessment. The list of activities, parameters which describe functional relations between time and cost, and the probability distributions of time and resources required must be input into a network simulator. Previously, this input was in a batch mode and required a great deal of time consuming data processing and delay in receiving the processor output. RAPP is integrated with the network simulator, VERT. Thus, once the network is created by RAPP and the necessary data inserted in RAPP, data files are created which can be read directly into VERT. Internal RAPP logic insures that this data is consistent with VERT data requirements. This method of creating a network is a major departure from the older "batch" mode of data entry; not only is it faster, it is also much easier and provides a better response to project managers.

What Does VERT Do?

VERT is the major network simulator into which the data, developed by the user with RAPP's help, is input. This network simulator addresses schedule, cost and technical risks, and their impacts on a weapon system acquisition program. The network simulation should provide the project manager with information for formulating initial project scheduling and acquisition strategy plans. It assists the user to:

- develop a project plan which meets management's time objectives
- establish realistic schedules
- measure the impact of alternative decisions on overall project performance before firm policies are laid down
- highlight project activities and problems requiring special attention early enough to allow preventive measures to be taken.

VERT, like similar network simulation software packages, is used to determine the interrelated schedule and cost risks resulting from time, cost, and technical performance uncertainties. For some efforts, the analysis might address only schedule risk. For other requirements, cost might be the only issue. When used at its full capability, the model serves other management purposes such as project estimating, planning, scheduling, resourcing, costing, and control. Additionally, VERT can be coupled to a computer graphics package to develop computer generated networks and X-Y plots.

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